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14. ABSTRACT

This report results from a contract tasking Instituto Superior Tecnico as follows: The Grantee will investigate the aeroelastic performance of the joined wing concept. Dr. Suleman and his research team have proposed to investigate the aeroelastic performance of the joined wing concept by analyzing, designing, manufacturing, and wind tunnel testing a aeroelastically scaled models. The first step will include designing a test assembly to conduct aeroelastic flutter and gust response tests. A fairly flexible wing with low bending and torsion mode frequencies is envisioned in order to study the aeroelastic phenomena in a low subsonic regime. The structure of the joined wing will be analyzed in order to determine its vibrational behavior. Design aspects to be considered include the spanwise loadings and the design of wing camber and twist. A comparison of experimental and computational results will be conducted. Nonlinear structural issues will also be addressed. In order to predict the post-buckling behavior of the joined-wing structure, this task will concentrate on the development of higher-order geometric nonlinearity models for the joined-wing concept. Appropriate criteria will be determined for (a) stiffness and weight effects on vehicle handling and flutter, and (b) ultimate strength and stability; (c) skin postbuckling and stringer column buckling of skin/stringer configurations, and (d) critical damage conditions associated with ultimate strength.

15. SUBJECT TERMS
EOARD, Aerodynamics, joined-wing, Aeroelasticity

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RESEARCH AND DEVELOPMENT OF A SCALED JOINED-WING FLIGHT VEHICLE

Year 1 Final Report
April 2004 – March 2005

Principal Investigator:
Afzal Suleman

Research Collaborators:
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Antonio Costa (Laboratory Technician)

April 2005

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1. Executive Summary

This work is concerned with the modeling and testing of an aeroelastically scaled test article of the “Joint Wing Concept”, proposed by Dr. Maxwell Blair at AFRL and Dr Robert Canfield at AFIT [1]. The experimental results obtained in a low-speed wind tunnel are to be compared and validated with the computational results obtained using NASTRAN and ZAERO.

To design and manufacture the aeroelastically scaled model, it is necessary to calculate the dynamics characteristics of the structure in terms of its natural frequencies, the stiffness and mass distribution of the structure. To that end, the aeroelastic data for the full aircraft has been obtained using MSC.NASTRAN and ZAERO. The scaling parameters aim to reproduce the scaled mass distribution, and the bending and torsional stiffness.

The research team comprises the principal investigator (Prof. Afzal Suleman), one PhD student (Pedro Ezequiel Pereira), one BSc Research Assistant (Luis Almeida) and one technician that is manufacturing the wind-tunnel models (António Costa). In terms of initial results, the natural frequencies for the full-scale aircraft have been obtained and the transfer of the modal information to the aeroelastic modeling software (ZAERO) has been completed. Dynamic analysis results have already been obtained in terms of the natural frequencies, the dimensions of the aeroelastic model have been calculated. The aeroelastic analysis and scaling have been completed and the manufacture of the model has been initiated. The 2nd year of the project proposes to carry out the wind-tunnel and ground vibration tests and correlated the experimental and computational results obtained so far.

In the 2nd year of the project, agreement has been reached with Professor Robert Canfield to have U.S. Air Force Major Vanessa Rebello to spend a month in 2006 in the Aeronautics Laboratory in Portugal working on a scaled flight test article. Major Rebello will be working in collaboration with the researchers at in Lisbon on the Joined-Wing Project.

2. Background and Motivation

The joined-wing concept has been studied by researchers and aircraft designers ever since Wolkovich proposed this concept in 1986 [2]. Joined wing configurations have been considered for a number of aircraft and other aeronautic applications with some of the ideas carried into experimental research aircraft. This kind of configuration provide some advantages such as low induced drag, minimal internal construction, high lift device, high altitude operation, great fuel economy, minimal operation cost, low maintenance, precise manufacturing technique and minimal internal structure. The weight advantages of the joined-wing concept have not been realized yet. Some studies indicate that the concept is not weight competitive with existing commercial carriers. However these conclusions have been based on simplistic models.

Various studies provided some important knowledge about the joint-wing behavior. Weisshaar and Lee [3] have provided considerable insight into the important role of flutter in constrained joined-wing design. Blair and Canfield [4] have examined the buckling response of a linear and nonlinear fully stressed design, concluding that the buckling mode shape tends to unload the outboard wing tip. It is critical to understand this effect in order to produce an aeroelastically fail-safe design. Other unresolved aeroelastic issues include the handling qualities, especially for take-off and landing in the presence of gusts.

The goal of the present work is to investigate the aeroelastic performance of the join-wing concept by designing, manufacturing, wind-tunnel testing an aeroelastically scaled model and computational testing of the wing in ZAERO. In order to resolve the issues mentioned, the following aspects are being probed further:

- Develop an efficient experimental test methodology to study the aeroelastic response of the joined-wing concept;
- Conceptualize, design and manufacture a static aeroelastic scaled model for the joined-wing concept based in [1];
- Verify and tune the scaled model;
- Collect data and evaluate the aeroelastic performance of the concept.

3. Work Description

3.1. The Joined-Wing Design

Blair and Canfield [1] have used the mission profile of the Global Hawk published on 12 August 1999. The Global Hawk is a surveillance airplane used by NATO and the USAF. The mission profile is summarized in Table 1.

Figure 1 Joined-Wing Aircraft Applications

	Ingress	Loiter	Egress
Range	3000 nm 5550 km	NA	3000 nm 5550 km
Duration	NA	24 hr 8.64E4 sec	NA
Velocity	0.6 Mach @ 50 Kft 177 m/s	0.4 Mach @ 65 Kft 118 m/s	0.6 Mach @ 50 Kft 177 m/s
C(SFC)	2.02E-4 (1/sec)	1.34E-4 (1/sec)	2.02E-4 (1/sec)
Dynamic Pressure	2939 Pa	638 Pa	2939 Pa

Table 1 - Baseline Aerodynamic Parameters

The baseline configuration is defined by the main wing configuration, thickness, aft wing vertical offset, twist-actuated aft wing and materials. The configuration is driven by a significant number of parameters, some of which are listed in Table 2. The materials used in this study include isotropic aluminum and a composite structure in a combination of Astroquartz, Carbon-Epoxy, and HRP foam core for the skins and just carbon-epoxy in the other parts of the structure.

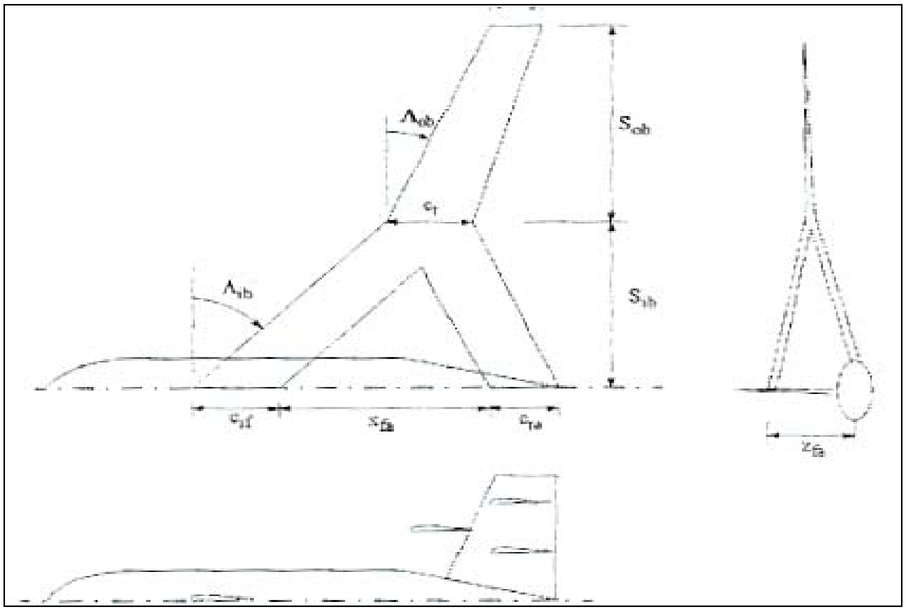


Figure 2 - Plan form Configuration

S_{ib}	26.0 m
S_{ob}	6.25 m
c_{rf}	2.50 m
c_{ra}	2.50 m
c_m	2.50 m
c_t	2.50 m
x_{fa}	22.0 m
z_{fa}	7.0 m
Λ_{ib}	30 deg
Λ_{ob}	30 deg
Airfoil	FX-60-126-1
Calculated Planform Area	145.0 m^2
Calculated Wing Volume	52.2 m^3

Table 2 - Baseline Configuration Parameters

3.2. Model Design Parameters

To construct an aeroelastic model, the proper scaling of model characteristics is important. Since the model geometric ratio affects other parameters, it is usually fixed by consideration of wind tunnel limitations. The maximum model span that the tunnel can accommodate sets the ratio b_M/b_W, where the subscripts refer to the model and full scale wing. The quantity b can be any linear dimension, although wing span is more convenient to use. The

scaling parameters should duplicate the scale stiffness, mass distribution, bending and torsional stiffness. The ratios are derived in [5] and become:

- Total mass or weight ratio,

$$\frac{M_M}{M_W} = \frac{\rho_M}{\rho_W}\left(\frac{b_M}{b_W}\right)^3 \qquad (1)$$

- Frequency ratio,

$$\left(\frac{V}{b\omega}\right)_M = \left(\frac{V}{b\omega}\right)_W \qquad (2)$$

- Velocity ratio,

$$\frac{V_M}{V_W} = \left(\frac{b_M}{b_W}\right)^{1/2} \qquad (3)$$

- Stiffness ratio,

$$\frac{EI_M}{EI_W} = \frac{\rho_M}{\rho_W}\left(\frac{V_M}{V_W}\right)^2\left(\frac{b_M}{b_W}\right)^4 \qquad (4)$$

3.3. Tunnel Limitations

For the WT tests it will be used a closed horizontal Gottingen type of tunnel. It is capable of operating between 5 and 70m/s with temperature control air stream. The test section is 2m long and a section 1.2m x 0.8m and can be used in an open or closed configuration. A uniform flow velocity with less than 0.8% can be obtained in a cubic zone 1.1m x 0.6m x 1.4m. The main limitation is for the wing span that as to be **1.1m** long, in order to maintain all the wing in an uniform flow.

3.4. Results

The use of MSC.NASTRAN enables us to perform the calculations of some parameters needed for the model design namely the natural frequencies and modes of vibration. This is done by performing a normal mode analysis.

This software is also used to calculate, tension distribution (Von-Mises) and deformation using a linear static analysis. The calculations where performed for two different files,

mpfsdelement.dat the aluminum model and ***testmaps1.dat*** the composite model. The methods used by the software are described in [6].

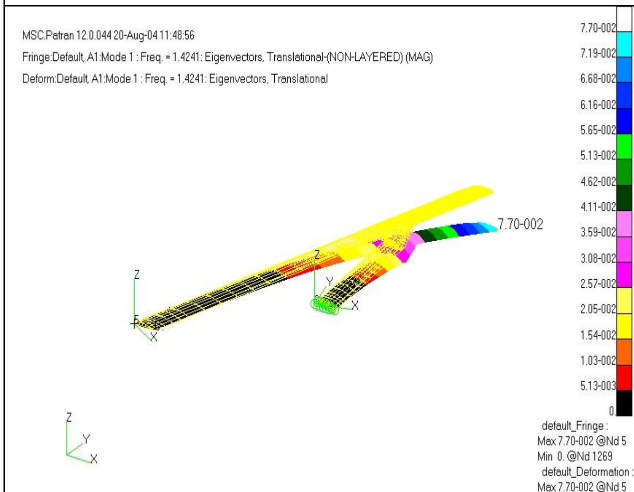
The results presented in Figures 3 and 4 present the modal analysis results for both the aluminum and composite aircraft based on input data provided by Canfield and Blair [1,7]. The first 4 frequencies are presented with the associated modal shapes. The system frequencies obtained are in agreement with other reported studies on joined wing aircraft.

Figures 5 and 6 show the regions of high stress for the joined wing and this information will be used when designing and manufacturing the wind-tunnel model to identify regions of possible failure and also prone to buckling failure. These results are currently being further investigated for input to WP-2 activities.

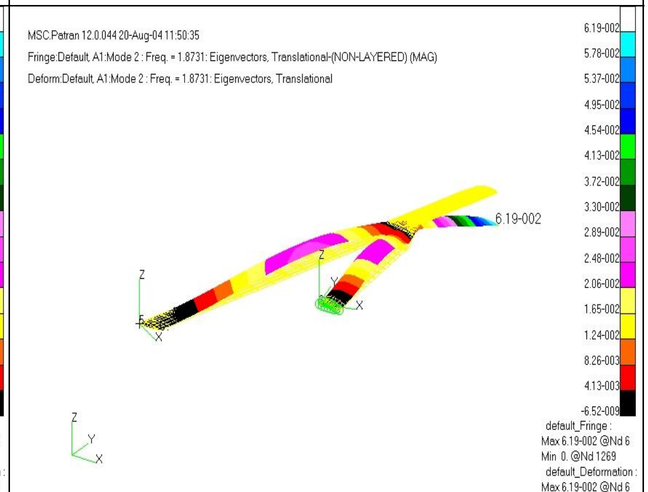
To find the model characteristics, the equations presented in Model Design Parameters are implemented in the software MATLAB. In the program all the dimensions, mass and stiffness are calculated. The stiffness of the main wing is also calculated in this program.

Aluminum Structure

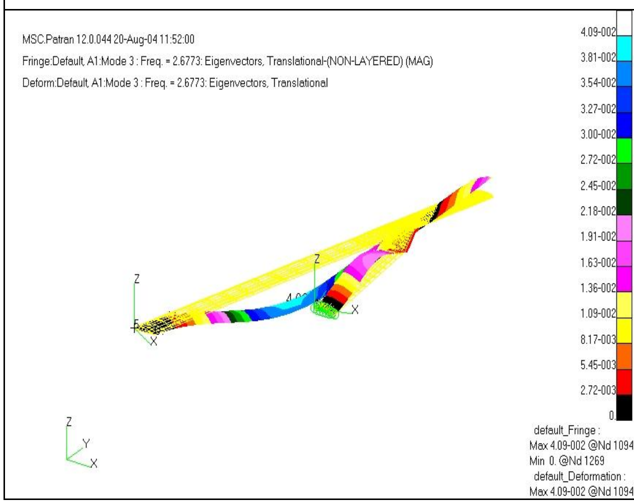
Mode 1, ω=1.4241 Hz



Mode 2, ω=1.8731 Hz



Mode 3, ω=2.6773Hz



Mode 4, ω=4.1853Hz

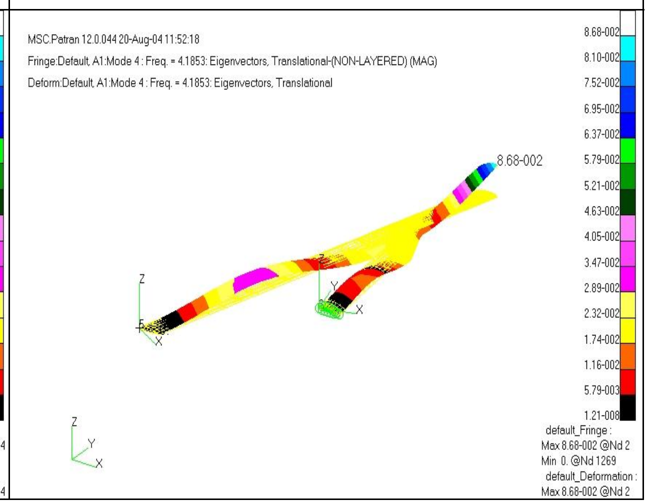
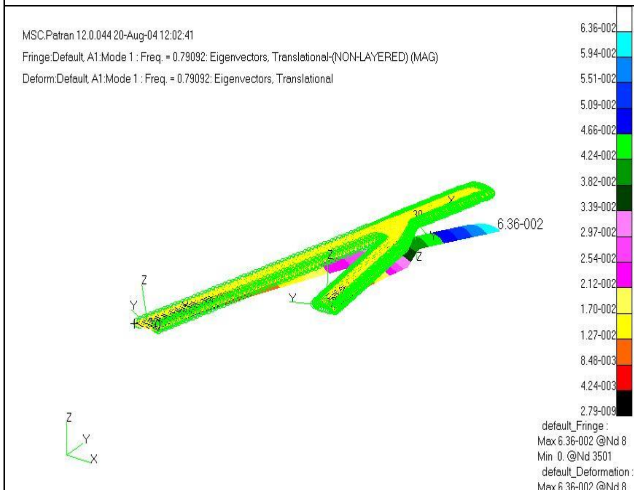


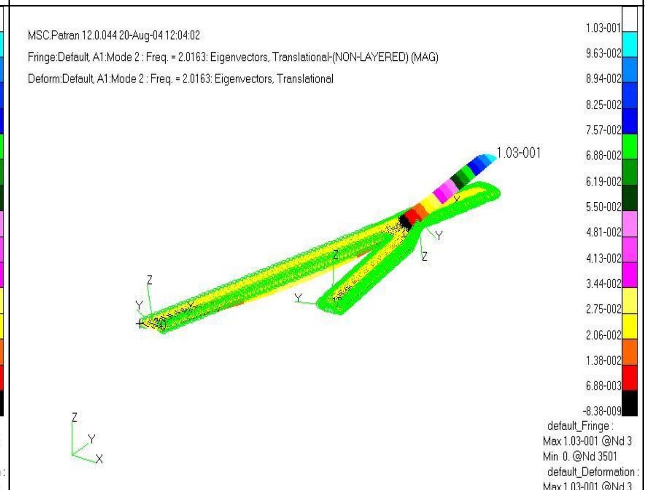
Figure 3 - Modes of vibration 1 to 4 for the aluminum structure

- Composite Structure

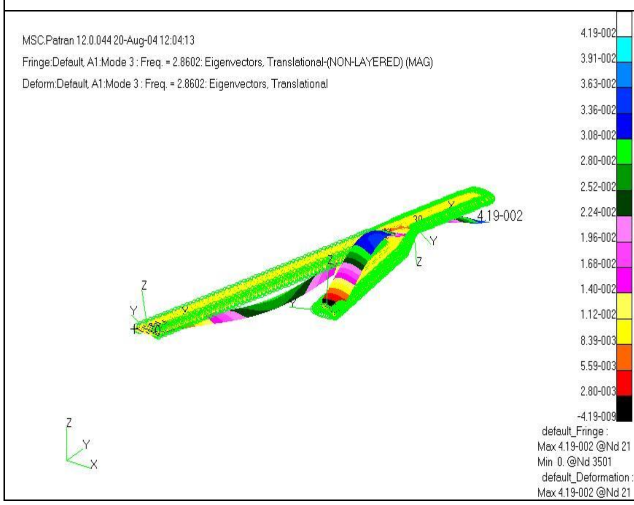
Mode 1, ω=0.79092 Hz



Mode 2, ω=2.0163 Hz



Mode 3, ω=2.8602Hz



Mode 4, ω=4.3354Hz

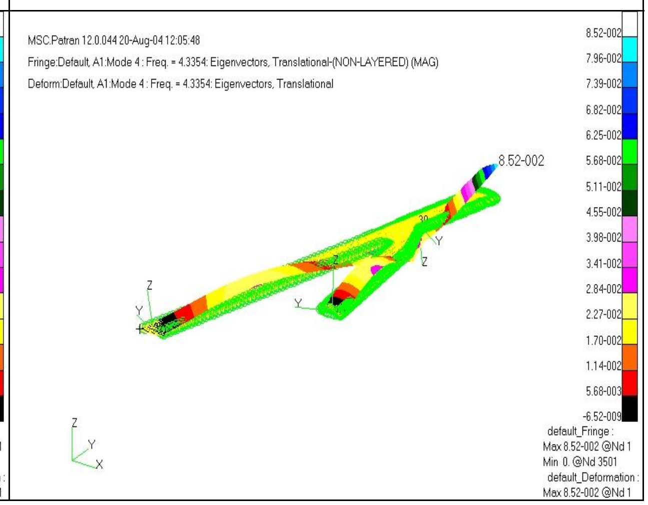


Figure 4 - Modes of vibration 1 –4 for the composite structure

The next results show the areas where maximum tensions are reached following the criteria of Von-Mises. It is also shown the deformed structure and it is posted the maximum deformation. Again the results are posted for both structures.

- Aluminum Structure

Maximum Deformation, 4.79m	Maximum Tension, 2.17E8 Pa

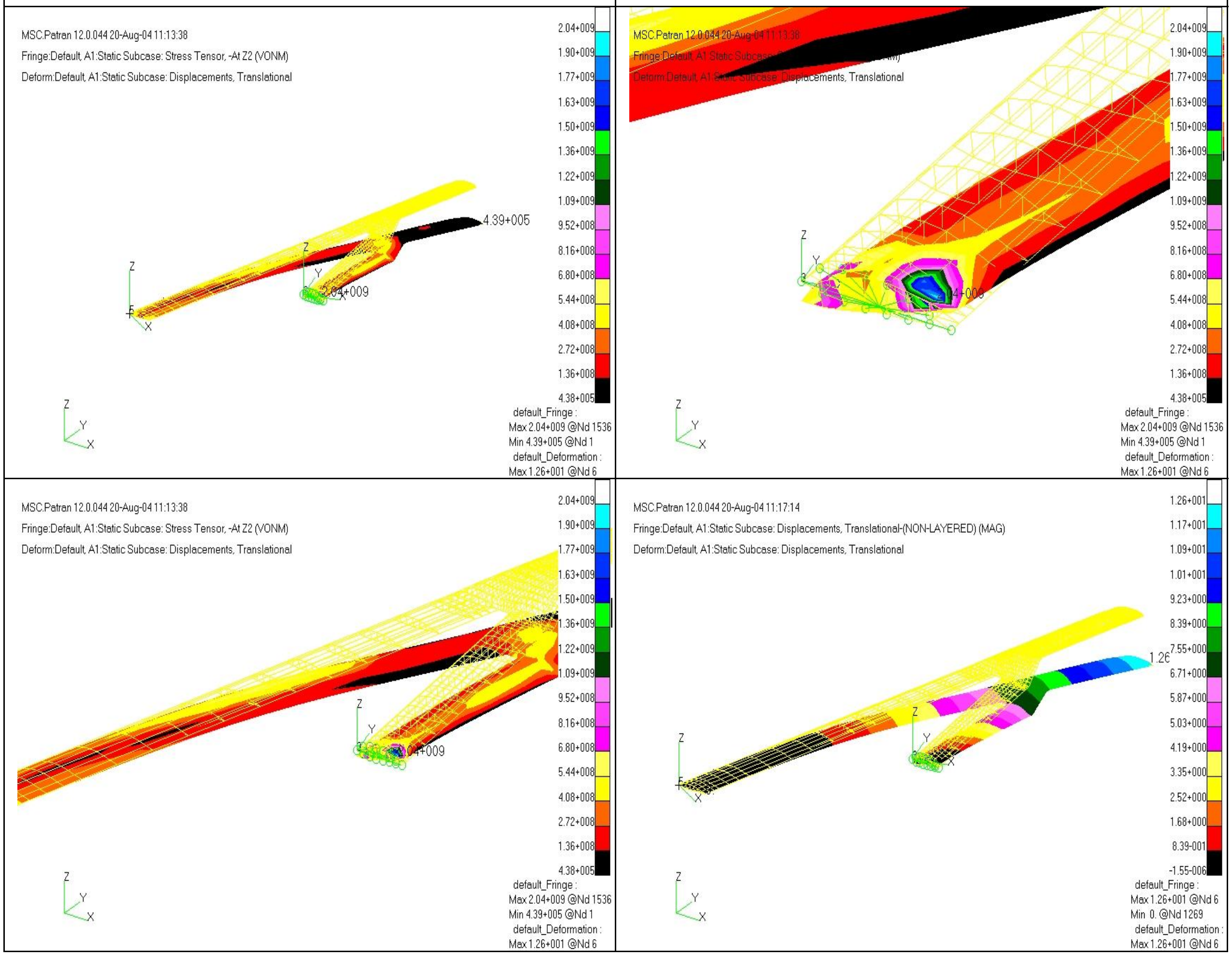


Figure 5 - Values and critical zones of stress in the structure for the aluminum structure

- Composite Structure

Maximum Deformation, 3.93m	Maximum Tension, 4.49E8 Pa

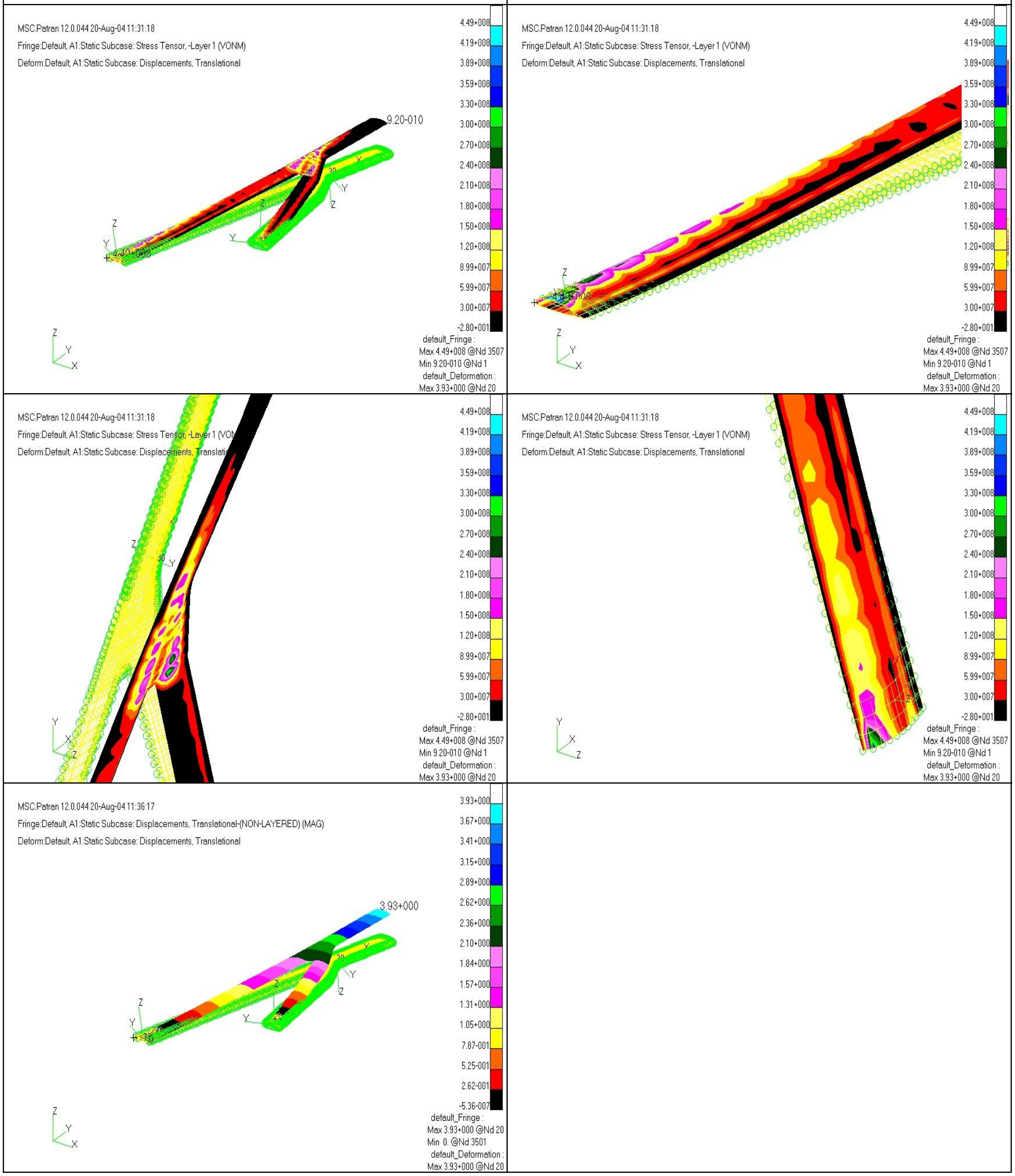


Figure 6 - Values and critical zones of stress for the composite structure

Table 3 shows the dimensions of the model; these values depending only on the ratio b_M/b_W=0.0310. They are the same for both structures.

S_{ib}	1.0.m
S_{ob}	0.194m
c_{rf}	0.077m
c_{ra}	0.077m
c_m	0.077m
c_t	0.077m
x_{fa}	0.682m
z_{fa}	0.217m
Λ_{ib}	30 deg
Λ_{ob}	30 deg
Airfoil	FX-60-126-1

Table 3 - Model Dimensions

To perform the calculation of the structure stiffness, we made an approximation to a beam, in order to use the following equation.

$$\omega_1 = (\beta l)^2 \sqrt{\frac{EI}{ml^3}} (rad / s),$$

where βl=1.875, m is the mass of the structure, calculated by MSC.NASTRAN in Kg and l is the span of the main wing. We solve this equation in order to EI to get the stiffness of the structure.

	Aluminum	**Composite**
EI (Nm2)	8.5590e+08	1.5083e+008
EI (model) (Nm2)	1.6019e+002	2.8230e+001
Mass (Kg)	3940	2251
Mass (model) (Kg)	0.7669	0.4382
Frequency (model) (Hz)	8.0873	4.4916

Table 4 - Properties of wing and model

4. SUMMARY OF TASKS COMPLETED (YEAR 1)

This section summarizes the current status of the project. Table 1 presents the values for the first five natural frequencies for the real wing with no fuel added.

Normal Freq.	**Value (Hz)**
1^{st}	0.7909
2^{nd}	2.0163
3^{rd}	2.8602
4^{th}	4.3354
5^{th}	7.0146

Table 5 – Wing Natural Frequencies.

The objective is to produce a wing model that fits in the wind tunnel dimensions, available at AFA-FAP and that re-creates with accuracy the dynamic behavior of the wing. To this end, we use the scaling equations for the various model characteristics for low speed wind tunnel. Note that the subscripts *W* and *M* relate to wing and model characteristics. Using Equations (1-4), we obtain the results for the model characteristics, presented in Table 6. The highlighted fields represent the most important results for the modeling.

EI	$28.2288 Nm^2$
Mass	0.4382 Kg
V	$31.1680\ ms^{-1}$
Normal Freq.	**Value (Hz)**
1^{st}	4.4916
2^{nd}	11.4505
3^{rd}	16.2429
4^{th}	24.6201
5^{th}	39.8355

Table 6 – Theoretical results for wing model.

Having these general results, we began to think how the model could be and what materials could be used. We reached the conclusion that a very simple model could be produced by using a core and a shell. With this in mind, we searched for materials that could reproduce the values obtained theoretically. We started looking at the popular materials used in modeling, such as Styrofoam for the core and composite materials such as E-glass for the shell. After some iteration, we obtained the final materials, number of plies, orientation angles, etc. The results are posted in Table 7, for two different models.

	Core	Shell
Name	Cork	E-glass[1]
	Cork	IM7[1]
ρ(kgm^{-3})	340.41	1980
	340.41	1554
Nº plies	-	1
	-	1
Ply Orient.[2]	-	60º
	-	60º
Thickness(m)	-	0.00015
	-	0.000135

Table 7 – Characteristics of the two core models.

However, although these models recreate with some accuracy the mass and the first natural frequencies, the errors increase significantly for the next natural frequency as it can be seen in Table 8, not reproducing accurately the dynamic behavior. With only the possibility of doing topological optimization, that is difficult, we began to work with other models using spars and ribs made of different material. Nevertheless, work is continuing also using the core models, as their simplicity will allow us to run some tests to verify preliminary design calculations.

	Theo.	**Model 1**	**Error (%)**	**Model 2**	**Error (%)**
Mass	0.4382	0.4456	1.69	0.4210	3.92
ω (Hz)					
1st	4.4916	4.5083	0.37	4.5774	1.91
2nd	11.4505	12.8413	12.14	13.0627	14.08
3rd	16.2429	20.0541	23.46	20.4855	26.12
4th	24.6201	30.7770	25.00	31.7870	29.11
5th	39.8355	48.0773	20.68	49.2327	23.59

Table 8 – Results obtained and comparison with theoretical values.

We are now running simulations in NASTRAN to get the final results. Two different models are currently under investigation. One of the models varies the thickness of the ribs and shell, and the mass is the first constraint (**Model 1**). The material used in ribs and spars is balsa wood and for the shell polycarbonate plastic has been used. For the second model (**Model 2**), the variable parameters are the thickness of spars ribs and shell, using aluminum as the material for the complete wing.

[1] Composite with Epoxy Resin
[2] Referenced by local coordinate axis.

To manufacture the wing, it was necessary to produce molds. Due to the complexity of the structure, it was decided to divide the structure into four components as presented in Figure 7. The final models will be an assembly of these components.

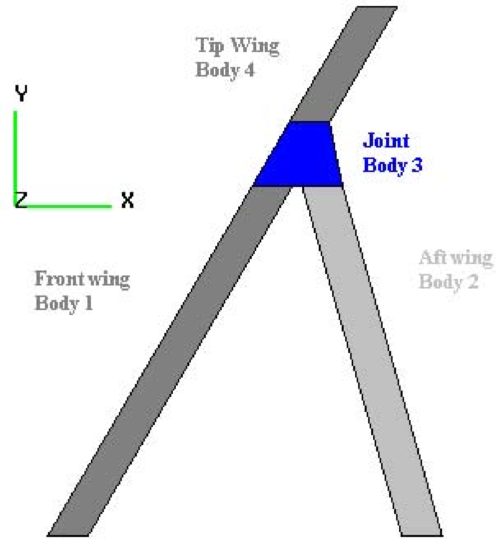


Figure 7 – Fragmentation of the body.

Figure 8 illustrates the foam molds. It can be seen that the body 3 is the most difficult to build due to its complexity. The next steps are to build the core model for initial tests and for the construction of spar and rib models, for final wind tunnel aeroelastic tests. To realize the tests, the wing will be mounted on a lateral wall of the tunnel, in order to maximize the wing span.

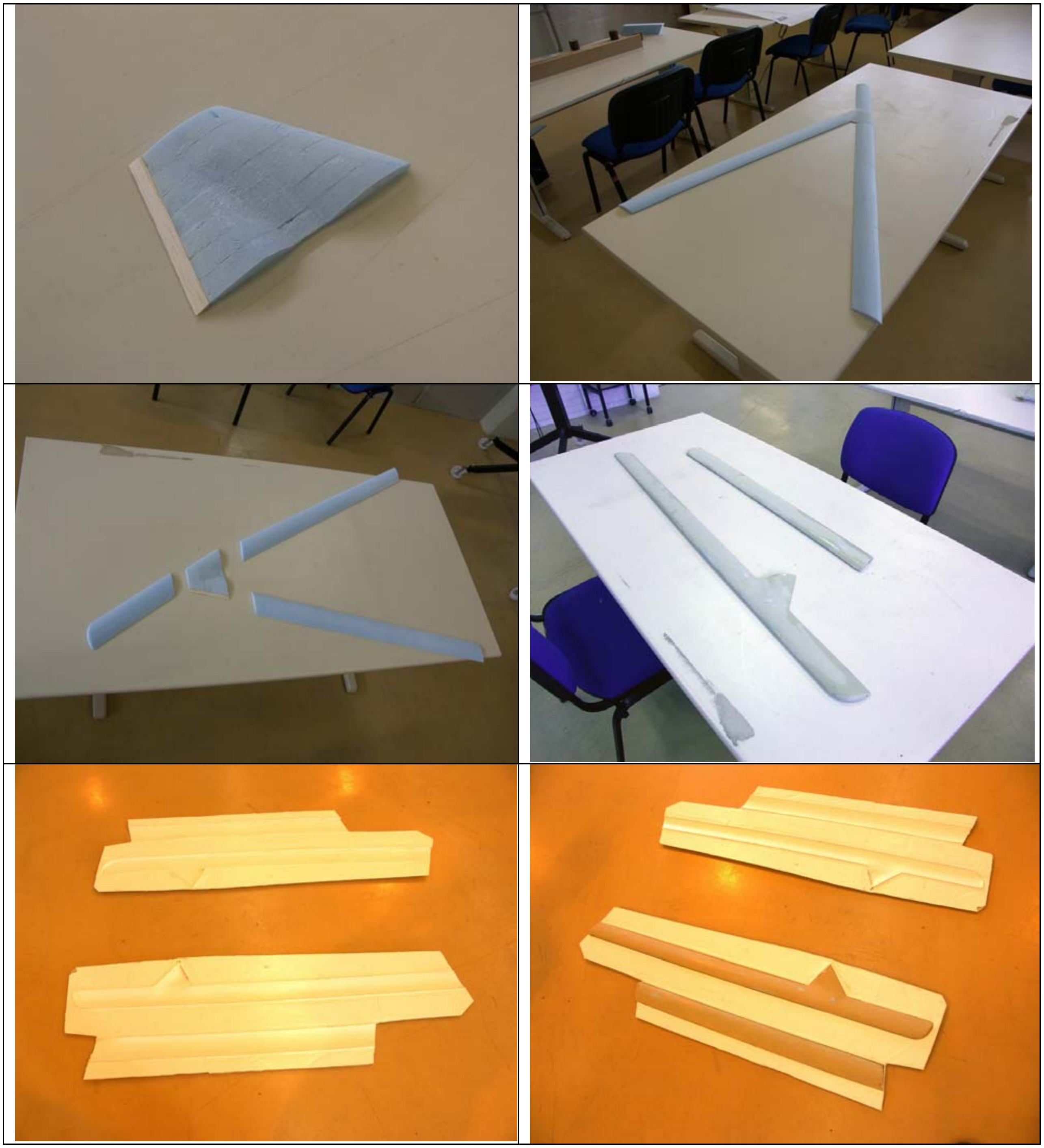
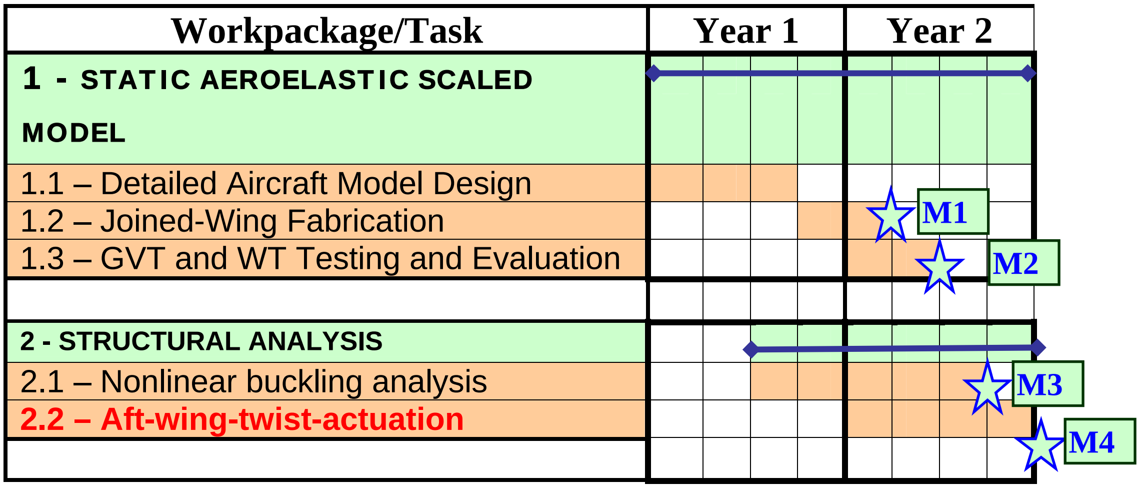


Figure 8 – Manufacturing of the Joined Wing WT molds.

5. Schedule



WP 1 – STATIC AEROELASTIC SCALED MODEL
(APRIL 2004 – MARCH 2005)

Task 1.1 – Detailed Aircraft Model – **completed** M1

Task 1.2 – Joined-Wing Fabrication –**initiated**

Task 1.3 – GVT and WT Testing and Evaluation – April 2005 – September 2005 M2

WP 2 –STRUCTURAL ANALYSIS AND OPTIMIZATION
(JUNE 2005 – MARCH 2006)

Task 2.1 – Nonlinear buckling analysis– the delay in WP 1 does not affect the outcome and planning of WP 2. **September 2005-December 2005** M3

Task 2.2 – Conceptual design and effect of aft-wing twist actuation mechanism. Details of the mechanism to be determined after consultation with Max Blair and Bob Canfield. **January 2006 – March 2006** M4

Total Effort (MM)

Personnel	Year 1 (actual)	Year 2 (planned)
Afzal Suleman (P.I.)	3	3
Pedro Ezequiel Pereira (PhD Student)	12	12
Luis Almeida (Research Engineer)	6	12
Antonio Costa (Lab Technician/Model Builder)	3	6
TOTAL EFFORT (MM Year 1)	**24**	**33**

6. References

[1] Blair, Maxwell, Canfield, Robert A., *A Joined-Wing Structural Weight Modeling Study*, AIAA-2002-1337

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[4] M. Blair and R.A. Canfield, “A joined-Wing Structural Weight Modelling Study”, AIAA 2002-1337, 43rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, Denver, CO, April 2002.

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[6] MSC.PATRAN MSC.NASTRAN, Online Help

[7] Roberts, Ronald, Canfield, Robert A., and Blair, Maxwell, “SensorCraft Structural Optimization and Analytical Certification,” 44th AIAA/ASME/ASCE/AHS Structures, Structural Dynamics, and Materials, 2003.

APPENDIX A: AEROELASTIC ANALYSIS RESULTS

The addendum to the project refers to the research results obtained between September and November 2004. These results pertain to the aeroelastic characteristics of the composite wing for different phases of the flight, with and without fuel.

There are 14 test cases considered as shown in Table A.1. To fit the aerodynamic model with the FE model, we have divided the wing into four(4) different parts: the front wing, the aft wing, joint body and the tip wing, as illustrated in Figure A.1 All of these parts are assembled in the ZAERO input files.. ZAERO uses a high-order paneling model.

Table A.1 – Flight Parameters for Aeroelastic Simulations

Case	Fixed Parameter	Value	Variable Parameters	Range
1	None		Vel: Altitude	118 m/s:0-65 Kft
				117m/s:0-65Kft
2	Altitude	65 Kft	Mach	0.1-0.75
3	Altitude	50 Kft	Mach	0.1-0.75
4	Altitude	30 Kft	Mach	0.1-0.75
5	Altitude	10 Kft	Mach	0.1-0.75
6	Altitude	0 Kft	Mach	0.1-0.75
7	Mach	0.1	Altitude	0-65Kft
8	Mach	0.2	Altitude	0-65Kft
9	Mach	0.3	Altitude	0-65Kft
10	Mach	0.4	Altitude	0-65Kft
11	Mach	0.5	Altitude	0-65Kft
12	Mach	0.6	Altitude	0-65Kft
13	Mach	0.7	Altitude	0-65Kft
14	Mach Density	0.6 1.225 kg/m^3	Velocity	10-330m/s

A.1 Composite Structure(No Fuel)

The results are presented in the Tables A.2 and A.3.

Table A.2 – Aeroelastic simulation results for the composite structure with no fuel

Case No.		g-method		K-method	
		f (Hz)	V (m/s)	F (Hz)	V (m/s)
1	Flutter	4.84	177	-	-
4	Flutter	4.44	223	-	-
5	Flutter	4.94	177	-	-
6	Flutter	5.06	162	-	-
11	Flutter	4.98	168	-	-
12	Flutter	4.77	192	-	-
13	Flutter	4.44	215	-	-
14	Flutter	4.88	162	4.19	169
		7.40	308	-	-
		12.50	311	12.56	249
	Divergence	-	-	-	197

Test Case 1 flutter occurs for the fourth structural mode at an altitude corresponding to a density of $8.968e^{-1}$ Kg/m^3. For test Cases 2,3 no flutter neither divergence occurs. In the case of the damping, no mode crosses the zero-axis of the graphic showing that no flutter occurs. This is an important result because these two altitudes belong to the mission profile. For Test Case 4, corresponding to M=0.74, flutter occurs for structural mode number 4. For test case 5, corresponding to M=0.67, flutter occurs for the 5th structural mode. For Test Case 6, the associated Mach is 0.47, associated with the 5th structural mode. For test cases 7, 8, 9 and 10, no flutter occurrences are detected. The graphics of Damping vs. Altitude show no crossings of the zero axis for any altitude at the Mach considered. An interesting situation occurs for structural mode 1. At a certain altitude and Mach number, it makes an inflection and gets close to the zero-axis. See also that as mach number grows so does the altitude at it occurs. For test case 11, corresponding to M=0.5, flutter occurs at an altitude that corresponds to the density of $1.11Kg/m^3$, which means at an 1085m of altitude in an ISA atmosphere and associated to structural mode number 5, in the absence of artificial damping. Test Case 12 has also a situation of flutter related to structural mode 4 at an altitude of 4949m (ISA).

With a M=0.7, Test Case 13 has an occurrence of flutter at the altitude of 8086m for structural mode 4(fig 4.23). For the last test case (#14), it was determined a divergence speed for a density

of 1.225Kg/m^3 and flutter for the structural modes 4 and 6 for g and K-method and for mode 9 in g-method.

A.2 Composite Structure(With Fuel)

Table A.3 – Aeroelastic simulation results for the composite structure with fuel

Case No.		g-method		K-method	
		f (Hz)	V (m/s)	F (Hz)	V (m/s)
1	Flutter	0.45	141	-	-
		0.83	177		
4	Flutter	0.45	167	-	-
		0.82	226		
5	Flutter	0.0015	198	-	-
		0.43	124		
		0.83	169		
		1.46	246		
6	Flutter	0.42	112	-	-
		1.02	145		
		1.47	210		
10	Flutter	0.43	130		
11	Flutter	0.83	165	-	-
12	Flutter	0.42	179	-	-
		0.83	190		
13	Flutter	0.43	207	-	-
		0.83	213		
		1.47	232		
14	Flutter	0.43	107		
		0.83	145	0.82	141
		1.47	206	1.39	318
	Divergence	-	-	-	197

In Test Case 1, two flutter modes occur, the first for structural mode number 2 with an altitude corresponding to a density of 0.727Kg/m^3 and the second for mode 4 in density of 0.7642kg/m^3. For Test Cases 2 and 3 no flutter occurs as observed in the analysis for the structure without fuel. For Test Case 4, two modes of flutter are found, one associated with M=0.55 and the other with M=0.74 for the 2nd and 4th structural modes, respectively. For Test Case 5, four modes of flutter were found, corresponding to M=0.60, 0.37, 0.51 and 0.75 for structural modes number 1, 2, 4 and 6, respectively. Test Case 6 has 3 flutter modes for M=0.33, 0.42 and 0.62 for modes 2, 5 and 6 respectively. Again for Test Cases, 7, 8 and 9 no flutter occurrences exist. Corresponding

to an altitude of 3804m or 10Kft, one flutter mode found for Test Case 10, corresponding to structural mode 2. Test Case 11 has a flutter occurrence at 2701m for mode 4. Modes 2 and 4 are associated to flutter occurrences in Test Case 12 at 1083m and 5844m altitude. Referring to Test Case 13, there are 3 flutter situations for modes 2, 4 and 6 associated to the altitudes 13810m, 8762m, 2345m. For the last Test Case, 14, cases of flutter are calculated for modes 4 and 6 in g and K-method, for mode 3 in g-method. A divergence speed is also calculated.

A.3 Model Design Parameters

Table A.4 – Summary of Aeroelastic Scaling Results

Flight Profile	
Altitude	50,000 ft
Mach no.	0.6

Full Scale Sensorcraft Properties	
Wing span	32.25 m
Wing mass (aluminum)	3940 kg
Wing mass (composite)	2250 kg
f_1 (aluminum)	1.4 Hz
f_1 (composite)	0.8 Hz

Velocities	
Flight	177 m/s
Wind Tunnel	31 m/s

Ratios	
b_M/b_W	0.0310
q_M/q_W	0.2
EI_M/EI_W	1.87e-7

Model Dimensions	
S_{ib}	0.81 m
S_{ob}	0.19 m
C_{rf}	0.08 m
C_{ra}	0.08 m
C_m	0.08 m
C_t	0.08 m
X_{fa}	0.68 m
Z_{fa}	0.22 m
Λ_{ib}	30 deg
Λ_{ob}	30 deg
Airfoil	FX-60-126-1

Model Properties (composite)	
EI_W	1.5083e+008
EI_M	28.2288Nm2
Model mass	0.44 kg
f_1	4.49 Hz